03-SC-002, Project Engineering and Design (PED), Linac Coherent Light Source, Stanford Linear Accelerator Center

1. Significant Changes

There have been no significant changes to scope, cost, or schedule.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design Start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006	2Q FY 2003	4Q FY 2006	N/A	N/A	N/A	N/A
FY 2007	2Q FY 2003	4Q FY 2006	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2006	36,000	7,500	—	43,500	N/A	N/A
FY 2007	35,974[b]	7,500	—	43,474[b]	N/A	N/A

4. Project Description, Justification and Scope

These funds allowed the Linac Coherent Light Source (LCLS), located at the Stanford Linear Accelerator Center (SLAC), to proceed from conceptual design into preliminary design and definitive design. The design effort has been sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, working drawings and specifications, and provide construction schedules including procurements. The design effort has ensured that long-lead procurement items could be initiated and construction could physically start to support the baseline LCLS schedule.

The purpose of the LCLS Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray free-electron-laser (FEL) in the 1.5–15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems. This will be the world's first such facility.

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[a] Construction funding for this project is included in project 05-R-320. The estimates in section 3 are for PED only. The full project TEC and TPC, established at Critical Design 2 (Approve Performance Baseline), are $315,000,000 and $379,000,000, respectively.

[b] The TEC and TPC have been reduced by $26,000 due to the FY 2006 rescission.

The LCLS is based on the existing SLAC linac. The SLAC linac can accelerate electrons or positrons to 50 GeV for colliding beam experiments and for nuclear and high-energy physics experiments on fixed targets. At present, the first two-thirds of the linac is being used to inject electrons and positrons into PEP-II, and the entire linac is used for fixed target experiments. When the LCLS is completed, the latter activity will be limited to 25 percent of the available beam time and the last one-third of the linac will be available for the LCLS a minimum of 75 percent of the available beam time. For the LCLS, the linac will produce high-brightness 5–15 GeV electron bunches at a 120 Hz repetition rate. When traveling through the new 120-meter long LCLS undulator, these electron bunches will amplify the emitted x-ray radiation to produce an intense, coherent x-ray beam for scientific research.

The LCLS makes use of technologies developed for the SLAC and the next generation of linear colliders, as well as the progress in the production of intense electron beams with radiofrequency photocathode guns. These advances in the creation, compression, transport, and monitoring of bright electron beams make it possible to base this next generation of x-ray synchrotron radiation sources on linear accelerators rather than on storage rings.

The LCLS will have properties vastly exceeding those of current x-ray sources (both synchrotron radiation light sources and so-called "table-top" x-ray lasers) in three key areas: peak brightness, coherence (i.e., laser-like properties), and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing over 10^{11} x-ray photons in a pulse with duration of less than 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific applications in the chemical, material, and biological sciences. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific community, identified high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. These first five areas of experimentation are: fundamental studies of the interaction of intense x-ray pulses with simple atomic systems; use of the LCLS to create warm dense matter and plasmas; structural studies on single nanoscale particles and biomolecules; ultrafast dynamics in chemistry and solid-state physics; and studies of nanoscale structure and dynamics in condensed matter.

The experiments fall into two classes. The first follows the traditional role of x-rays to probe matter without modifying it, while the second utilizes the phenomenal intensity of the LCLS to excite matter in fundamentally new ways and to create new states in extreme conditions. The fundamental studies of the interactions of intense x-rays with simple atomic systems are necessary to lay the foundation for all interactions of the LCLS pulse with atoms embedded in molecules and condensed matter. The structural studies of individual particles or molecules make use of recent advances in imaging techniques for reconstructing molecular structures from diffraction patterns of non-crystalline samples. The enormous photon flux of the LCLS may make it feasible to determine the structure of a *single* biomolecule or small nanocrystal using only the diffraction pattern from a single moiety. This application has enormous potential in structural biology, particularly for important systems such as membrane proteins, which are virtually uncharacterized by x-ray crystallography because they are nearly impossible to crystallize. The last two sets of experiments make use of the extremely short pulse of the LCLS to follow dynamical processes in chemistry and condensed matter physics in real time. The use of ultrafast x-rays will open up entire new regimes of spatial and temporal resolution to both techniques.

The LCLS Project requires a 135 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one-third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new undulator and associated equipment. Two new buildings, the Near Experimental Hall and the Far Experimental Hall will be constructed and connected by a beam line tunnel. A Central Laboratory and Office Building will be constructed to provide laboratory and office space for LCLS users and serve as a center of excellence for basic research in x-ray physics and ultrafast science.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3 -1, Program and Project Management for the Acquisition of Capital Assets.

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—3Q FY 2001
- Critical Decision-1: Approve Preliminary Baseline Range—1Q FY 2003
- Critical Decision-2a: Approve Long-Lead Procurement Budget—3Q FY 2003
- Critical Decision-2b: Approve Performance Baseline—3Q FY 2005
- External Independent Review Final Report—3Q FY 2005
- Critical Decision 3a: Approve Start of Long-Lead Procurement—1Q FY 2005
- Critical Decision-3b: Approve Start of Construction—2Q FY 2006
- Critical Decision-4: Approve Start of Operations—2Q FY 2009

5. Financial Schedule (dollars in thousands)

	Appropriations	Obligations	Costs
Design by Fiscal Year			
2003	5,925 [a]	5,925 [a]	3,644
2004	7,456 [a]	7,456 [a]	9,713
2005	19,914 [a]	19,914 [a]	18,388
2006	2,518 [ab]	2,518 [ab]	4,056
2007	161 [a]	161 [a]	173
Total, Design PED (03-SC-002)	35,974	35,974	35,974

[a] PED funding was reduced as a result of the FY 2003 general reduction and rescission by $75,000, as a result of the FY 2004 rescission by $44,000, and as a result of the FY 2005 rescission by $161,000. This total reduction is restored in FY 2005, FY 2006, and FY 2007 to maintain the TEC and project scope.
[b] PED funding was reduced by $26,000 as a result of the FY 2006 rescission.

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design	35,974	35,974

Other Project Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Conceptual Planning	1,500	1,500
R&D	6,000	6,000
Total, OPC	7,500	7,500

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	35,801	173	—	—	—	—	—	35,974
OPC (Design)	7,500	—	—	—	—	—	—	7,500
Total, Project Costs	43,301	173	—	—	—	—	—	43,474

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach

A Conceptual Design Report (CDR) for the project was completed and reviewed in FY 2002. Key design activities are being specified in the areas of the injector, undulator, x-ray optics and experimental halls to reduce schedule risk to the project and expedite the startup. Also, the LCLS management systems have been being put in place and tested during the Project Engineering and Design (PED) phase. These activities are managed by the LCLS Project Office at SLAC, with additional portions of the project being executed by staff at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL).

The design of technical systems is being accomplished by the three collaborating laboratories. The conventional construction design aspect (experimental halls, tunnel connecting the halls, and a Central Laboratory and Office Building) was contracted to an experienced Architect/Engineering (A/E) firm to perform preliminary and final design. Preliminary design was completed in FY 2004. Final design began in FY 2005 and will be complete by the end of FY 2006.